A Study to Understand the Early Life History of Snake River Fall Chinook Salmon, 2006

Douglas M. Marsh, Jerrel R. Harmon, Neil N. Paasch, Kenneth L. Thomas, Kenneth W. McIntyre, William D. Muir, and William P. Connor

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Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

and

U. S. Fish and Wildlife Service
Idaho Fishery Resource Office
P.O. Box 18
Ahsahka, Idaho

for

Walla Walla District
Northwestern Division
U.S. Army Corps of Engineers
201 North 3rd
Walla Walla, Washington 99362-1876
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EXECUTIVE SUMMARY

We began a study in 2005 to document the downstream passage histories of returning adult PIT-tagged Snake River fall Chinook salmon *Oncorhynchus tshawytscha*. The study was undertaken in part to further understand the juvenile life history strategies of passive integrated transponder (PIT) tagged fish that were never detected during their juvenile migration. We analyzed data from adults recaptured at Lower Granite Dam from September to November 1998-2006. Scale samples were read to determine age at ocean entry (subyearling or yearling). Downstream passage histories were determined to the extent possible based on juvenile PIT-tag detections and age at ocean entry. The effects of age at ocean entry on time spent in seawater and fork length at return were also evaluated.

We analyzed data on a total of 134 returning fall Chinook salmon recaptured at Lower Granite Dam during 1998-2006. All fish had been tagged as subyearlings and released to migrate inriver during 1994-1998 and 2000-2004, when summer spill was limited at Snake River dams. Of the 134 adults, only 32 (24%) had entered the ocean as subyearlings, and only 6 of these 32 fish had never been detected as juveniles. Of the 134 adults, 102 had entered the ocean as yearlings. Of these 102 yearling ocean entrants, 31 were known to have spent their first winter in reservoirs and the remaining 71 in unknown freshwater/estuarine locations. We deduced that many of the 71 yearling ocean entrants likely wintered in reservoirs upstream from Bonneville Dam.

Recaptured fall Chinook salmon adults that migrated inriver during 1994-2004 provided baseline data for years with limited summer spill, whereas recaptured fall Chinook salmon jacks and mini-jacks that migrated inriver during 2005 provided the first baseline data for a year with summer spill (additional age classes yet to return).

Based on preliminary adult returns of inriver migrants, three trends were apparent indicating differences between spill and non-spill years for both Snake and Clearwater River fall Chinook salmon. For adults from the Snake River, the first trend was that the percentage of yearling ocean entrants decreased from 76% for the 1998-2004 releases to 13% for the 2005 releases. Second, the minimum percentage of fish that had been reservoir-type juveniles decreased from 22% for the 1998-2004 releases to 0% for the 2005 releases. Third, fewer subyearling ocean entrants passed downstream undetected during years when summer spill was limited (1998-2004) than when summer spill was fully implemented (2005).

For adult inriver migrants from the Clearwater River, the first trend was that the percentage of yearling ocean entrants varied little between fish released during

1998-2004 (82%) and those released in 2005 (88%). Second, there was little variation in the percentage of adults that had been reservoir-type juveniles between the 1998-2004 releases (36% or more) and 2005 releases (31% or more). Third, similar to results from the Snake River, fewer subyearling ocean entrants from the Clearwater River passed downstream undetected during 1998-2004 than in 2005. These trends should be followed as more data become available.

We recaptured 34 adult fall Chinook salmon at Lower Granite Dam that had been tagged as subyearlings, transported during summer, and released below Bonneville Dam. Of these transported fish, 76% had entered the ocean as subyearlings and 24% as yearlings after wintering in fresh or estuarine water. We recaptured an additional 15 fish that had been tagged as subyearlings and transported during fall. Of these, only 7% had entered the ocean as subyearlings, while 93% had wintered in fresh or estuarine water and entered the ocean as yearlings.

In addition to the subyearlings tagged and released above Lower Granite Dam, river-run subyearlings were tagged at Lower Granite Dam in September and October 2002-2005 and transported by truck to a release site below Bonneville Dam. During 2005 and 2006, we recaptured 80 returning fall Chinook salmon from this group. Thirty-six percent of these fish had entered the ocean as subyearlings, with the remaining 64% having entered as yearlings.

We found that subyearling ocean entrants were less likely than yearling ocean entrants to return after spending 1 year or less at sea (subyearlings produced fewer jacks and no mini-jacks). However, after omitting jacks and mini-jacks from consideration, yearling ocean entrants still comprised over half of the full-term adults. Full-term adults that had been yearling ocean entrants were usually similar in size or larger than full-term adults that entered the ocean as subyearlings.

We conclude that Snake River fall Chinook salmon juveniles employ diverse downstream passage and life history strategies to reach the sea. This diversity should be considered when planning recovery measures, designing dam-passage studies, and attempting to calculate smolt-to-adult return rates for release groups with different passage histories, particularly when undetected passage is prevalent.

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INTRODUCTION

The National Marine Fisheries Service began annual studies in 2001 to evaluate the efficacy of transporting Snake River fall Chinook salmon *Oncorhynchus tshawytscha* from lower Snake River hydropower projects (Marsh et al. 2003, 2004a,b, 2005). Subyearlings used in these studies included both wild and hatchery fall Chinook salmon. Hatchery fish were from Lyons Ferry Hatchery (Figure 1), and all study fish were implanted with passive integrated transponder (PIT) tags (Prentice et al. 1990a).

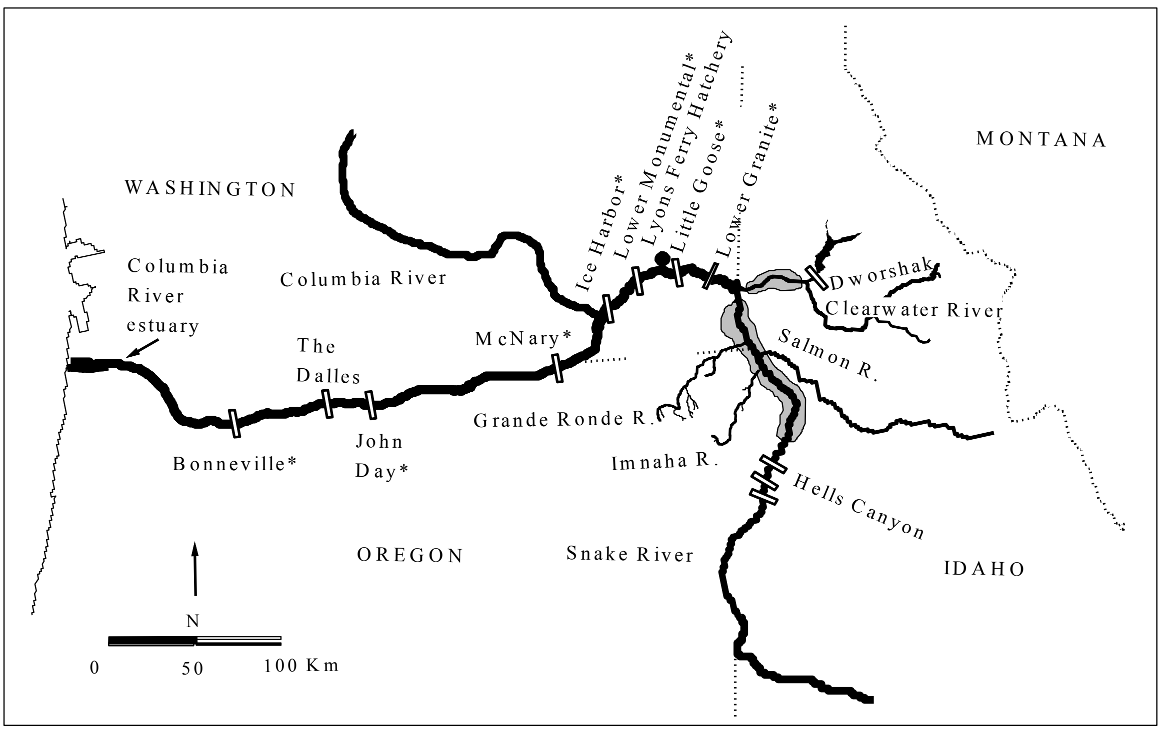

Figure 1. The Snake River and lower reaches of its tributaries (gray shaded areas) where wild fall Chinook salmon were hatched before being PIT tagged as subyearlings for life history/survival studies. Lyons Ferry Hatchery (open circle) provided subyearlings for the transport and dam passage strategy studies. Dams with juvenile fish bypass systems and PIT-tag monitors (Prentice et al. 1990b) are indicated by an asterisk.

The original study was designed to compare smolt-to-adult return rates (SARs) of transported subyearlings to those of subyearlings that migrated downstream in the Snake and Columbia Rivers without being detected in the juvenile bypass systems at dams. The SARs were to be calculated with methods developed for PIT-tagged spring Chinook salmon (Sandford and Smith 2002; Schaller et al. 2007). For transported fish, these methods would produce SARs based on a known number; whereas for undetected inriver migrants, SARs would be based on an estimate of the number of smolts that passed Lower Granite Dam via spillways or turbine intakes.

An underlying biological assumption of the SAR calculation method for undetected fish is that after release, smolts will continue active migration, passing through downstream dams while PIT tag monitors are operational. This assumption does not account for fish that discontinue migration after release and pass downstream through the hydropower system during winter, when juvenile bypass facilities (where the PIT-tag monitors are located) are not operating. These fish may pass downstream undetected through a combination of winter passage and spring passage during periods of spill. The assumption that fish will migrate after release is largely met for fall Chinook salmon that exhibit an ocean-type life history (Healy 1991) characterized by first-year wintering in seawater.

However, some fall Chinook salmon in the Snake River basin exhibit a "reservoir-type" juvenile life history, characterized by first-year wintering in reservoirs (Connor et al. 2005). For "reservoir-type" juveniles, undetected winter passage, as well as undetected spring passage during spill, has been documented in the hydropower system (Tiffan and Conner 2005). Consequently, the methods of Sandford and Smith (2002) and Schaller et al. (2007) for calculating SARs may not be suitable for all population segments of Snake River fall Chinook salmon (Buchanan and Skalski 2006).

Connor et al. (2005) concluded the reservoir-type juvenile life history was important to production of fall Chinook salmon in the Snake River Basin. They found an overall average of 41% of the wild adults studied had wintered in fresh water, according to scale pattern analysis. However, scale pattern analysis could not discriminate between adults that had spent their first winter in a reservoir and those that spent their first winter below Bonneville Dam in either freshwater or estuarine water. Therefore, the conclusion of Connor et al. (2005) relied on an assumption that has since been questioned: that among their study fish, no adult fall Chinook transported as a juvenile had overwintered in fresh or estuarine waters downstream from Bonneville Dam.

We began a study in 2005 to document the downstream passage histories of returning adult PIT-tagged Snake River fall Chinook salmon. The study was undertaken in part to further understand the juvenile life history strategies of PIT-tagged fish that were never detected during their juvenile migration. For the first year of this study, we analyzed data from 1998-2005 adult returns at Lower Granite Dam for fall Chinook salmon that had been tagged as subyearlings and migrated inriver to the sea. We found that 93 (79%) of these fish had entered the ocean as yearlings, and of these 93, 27 were conclusively shown to have spent their first winter as juveniles in reservoirs (Marsh et al. 2007). The remaining 66 had spent their first winter in unknown freshwater/estuarine locations, with 36 having completed their juvenile migration without being detected at a dam. We deduced that most of these 66 fish likely spent their first winter in reservoirs upstream from Bonneville Dam.

In this report, we expand findings from the first year (Marsh et al. 2007) with adult return data collected in 2006. This report has three objectives. The first is to describe the downstream passage histories of juvenile fall Chinook salmon that returned as adults to Lower Granite Dam from 1998 to 2006. We categorize downstream passage histories based on migration pathway (summer transport, fall transport, or inriver migrant), age at ocean entry (subyearling or yearling), and first-year wintering location (seawater, reservoir, fresh/estuarine water below Bonneville Dam, or unknown). The second objective is to evaluate the effect of age at ocean entry (subyearling or yearling) on time spent in seawater prior to return to fresh water as an adult. The third objective is to evaluate the effect of age at ocean entry on the size (fork length) of returning adult fall Chinook salmon.

To date, sample sizes of returning adults to address these three objectives have been small and do not fully represent all components and seawater age classes that make up the general population of Snake River Basin fall Chinook salmon. Consequently, we pooled data across release years, return years, seawater age classes, and between origins, genders, and rivers. The complete data set is provided in Appendix Table 1. Accumulation of samples that accurately represent the Snake River Basin population is the long-term goal of our study.

METHODS

From September through November 1998-2006, wild and hatchery fall Chinook salmon were collected in the adult trap at Lower Granite Dam (Harmon 2003) as they returned to spawn. Three groups of adult study fish were collected. The first group was composed of wild and hatchery subyearlings that had been PIT-tagged and released from 1994 to 2004 for life history/survival studies (Connor et al. 2002; Smith et al. 2003). None of these fish were transported: if collected at dams downstream from the point of release, they were routed back to the river to continue migration. The second group was composed PIT-tagged subyearlings released from 2001 to 2005 for transport studies (Marsh et al. 2003, 2004a,b, 2005; unpublished data). The third group was made up of subyearlings released in 2005 for a study to evaluate the response of Snake River fall Chinook salmon to differing dam passage strategies (Marsh and Connor 2004c). A portion of these fish were transported for release downstream from Bonneville Dam, while their cohorts were released to complete their juvenile migration inriver. We report results separately for the returns from the life history/survival, transport, and dam passage strategy studies.

Each study year, the PIT-tag codes of all subyearling Chinook tagged for research during the five preceding years were entered into the separation-by-code diversion system in the adult trap at Lower Granite Dam (Marsh et al. 1999; Downing et al. 2001). We collected scales from each adult fall Chinook salmon diverted and recaptured. Scales were placed in an envelope marked with a sequential sample number, and the recovery date and PIT-tag code of the sampled fish were recorded, along with gender and fork length. Scales were analyzed by John Sneva of the Washington Department of Fish and Wildlife (WDFW) to determine origin (wild or hatchery) and whether the first annulus was formed in seawater (seawater annulus) or in fresh water (freshwater annulus; see Connor et al. 2005). A seawater annulus indicated first-year wintering in seawater and age-0 ocean entry, whereas a freshwater annulus indicated first-year wintering in fresh or estuarine water and age-1 ocean entry.

We determined year of ocean entry from age at ocean entry. For example, if a juvenile was released in 1998 and entered seawater as a subyearling, then year of ocean entry was 1998. Scale-pattern analysis prior to 2005 preceded the compilation of juvenile PIT-tag histories and was conducted without knowledge of gender or fork length to ensure blind analysis of scale patterns. In all, 111 scales from fall Chinook adults were collected prior to 2005 and read. No age or origin classification errors were found. In 2005 and 2006, scale pattern analysis was incorporated with large-scale trapping and brood stock collection for Lyons Ferry Hatchery and the Nez Perce Tribal Hatchery.

Data reported for 2006 was error-checked by staff of WDFW before it was provided to us. We are presently working with WDFW to develop a long-term program for validating scale pattern analysis.

All fish in the life history/survival group completed their juvenile migration inriver. For fish from the transport and dam-passage strategy groups, one of three migration pathways were possible: summer transport (21 Jun-31 Aug), fall transport (1 Sep-13 Dec), or inriver migration. For these fish, we used PIT-tag detection histories to determine the juvenile migration pathway of each adult. Transport was confirmed based on PIT-tag detection on a flume leading to a transport-holding raceway. Inriver migration was confirmed by either detection on a flume leading back to the river (for fish that passed the dam via the juvenile bypass system), or by the absence of any juvenile PIT-tag detection (indicating fish passed the dam via turbines or spillways).

We were able to conclusively identify the first-year wintering location of some fall Chinook salmon recaptured at the adult trap based on the results of both scale-pattern analysis and juvenile PIT-tag detection history. If the scale had a saltwater annulus, then the fish had spent its first winter in saltwater. If the scale had a freshwater annulus, and the juvenile PIT-tag detection history included tagging in year t and detection at a dam in year $t + 1$, then the fish had spent its first winter as a juvenile in a reservoir.

If the scale had a freshwater annulus, the fish may also have spent its first winter as a juvenile in fresh or estuarine water downstream from Bonneville Dam. Conclusive identification of first-year wintering below Bonneville Dam required PIT-tag detection as a subyearling either on a flume leading to a transport-holding raceway or in the juvenile bypass system at Bonneville Dam. We were unable to conclusively determine first-year wintering location for returning fall Chinook salmon that possessed scales with freshwater annuli, but were never detected or were last detected upstream from Bonneville Dam as subyearlings. Preliminary work is being done to determine the feasibility of using otolith micro-chemistry to determine first-year wintering location of fish with these two juvenile PIT-tag detection histories.

We calculated time spent in seawater for each returning fall Chinook salmon by subtracting year of ocean entry from year of return. For example, a subyearling that was released in 1998, entered seawater in 1998, and returned to fresh water in 1999 was classed as a I-salt (Chinook salmon with this life history are males called jacks). A subyearling that was released in 1998, entered seawater as a yearling in 1999, and returned in 2000 would also be a I-salt (and also a jack). Fall Chinook salmon males that enter seawater as yearlings may also return to fresh water as "mini-jacks" after residing at sea for only a few months (Zimmerman et al. 2003). These fish mature and return to spawn in the same year they enter seawater. We considered only II-, III-, and IV-salt adults to be "full-term" adults.

We pooled results for fall Chinook salmon from the Snake and Clearwater Rivers to increase sample sizes for analysis of percentages by seawater class (I-, II-, III-, or IV-salt). All percentages were rounded to whole numbers, so percentages summed across individual seawater classes did not always equal 100%.

In most instances, fork length (cm) was measured on adult fish recaptured at the adult trap. To assess the effect of age at ocean entry on size at return, we evaluated mean fork length by time spent in seawater. For this analysis, we pooled the data for hatchery fall Chinook salmon from the Snake and Clearwater Rivers across all return years to increase sample sizes. In some instances, gender was assigned to adult fish recaptured at the trap. For fish whose gender had been determined, we calculated mean fork length by gender for full-term adults.

RESULTS

Life History/Survival Studies: Returns from 1994-2004

Snake River Fall Chinook Salmon

A combined total of 98 returning adults from the Snake River (wild n = 21; hatchery n = 77) that migrated inriver as juveniles were recaptured at Lower Granite Dam during 1998-2006. Data collected on 10 returning fish are not presented in Table 1. These fish were tagged as subyearlings in 1999, but PIT-tag monitors at the dams were changed to detect a new tag frequency late in 1999. This change resulted in fewer detections of fall migrants in 1999 and no detections of reservoir-type juveniles in spring 2000.

Across 1998-2006, 25% of the returning Snake River fish had been subyearling ocean entrants and 75% had been yearling ocean entrants (Table 1). The percentage of fish that had spent their first winter as juveniles in seawater, reservoirs, or unknown freshwater/estuarine locations calculated across years were 25%, 17%, and 58%, respectively.

Table 1. Age at ocean entry and first-year wintering location of adult fall Chinook salmon PIT-tagged and released into the Snake River as subyearlings for life history/survival studies (wild n = 16; hatchery n = 72). All fish migrated inriver as juveniles. Data from migration year 1999 were omitted.

			Last juvenile detection			
Age at ocean entry	First-year winter location	Across year composition N (%)	Summer (21 Jun-31 Aug) *n* (%)	Fall (1 Sep-10 Dec) *n* (%)	Spring (year *t* + 1) *n* (%)	Never detected *n* (%)
Age-0	Seawater	22 (25)	16 (73)	1 (5)		5 (23)
Age-1	Reservoir	15 (17)			15 (100)	
Age-1	Unknown	51 (58)	9 (18)	18 (35)		24 (47)

Clearwater River Fall Chinook Salmon

A total of 22 hatchery fish from the Clearwater River were recaptured as adults at Lower Granite Dam during 1998-2006 (Table 2). Data collected on 11 of these fish, which were tagged as subyearlings in 1999, are not presented in Table 2 because of the change in frequency of PIT-tag detectors (as described above for Snake River fish). Of the remaining 11 fish analyzed, 18% had entered the ocean as subyearlings and 82% had entered as yearlings (Table 2). First-year wintering location percentages calculated across years were 18% seawater, 36% reservoir, and 46% unknown freshwater/estuarine.

Both of the Clearwater River fish that spent their first winter in seawater were last detected in summer. Of the 5 inriver migrants that spent their first winter in unknown freshwater/estuarine locations, 3 passed downstream undetected, 1 was last detected in summer, and 1 was last detected in fall. The scales of all 4 returning adults that had been determined to be reservoir-type juveniles by PIT-tag detection had freshwater annuli. This again validated that correct ages at ocean entry were assigned by the scale reader.

Table 2. Age at ocean entry and first-year wintering location of adult hatchery fall Chinook salmon PIT-tagged and released into the Clearwater River as subyearlings for life history/survival studies (n = 11). All fish migrated inriver as juveniles. Data from migration year 1999 were omitted.

			Last juvenile detection			
Age at ocean entry	First-year winter location	Across year composition	Summer (21 Jun-31 Aug)	Fall (1 Sep-10 Dec)	Spring (year t + 1)	Never detected
		N (%)	n (%)	n (%)	n (%)	n (%)
Age-0	Seawater	2 (18)	2 (100)			
Age-1	Reservoir	4 (36)			4 (100)	
Age-1	Unknown	5 (46)	1 (20)	1 (20)		3 (60)

Time in Seawater

For adults from the Snake and Clearwater Rivers combined, time spent in seawater ranged from 1 to 3 years for subyearling ocean entrants and from less than 1 year to 4 years for yearling ocean entrants (Table 3). Subyearling ocean entrants did not return as mini-jacks, and they were less likely than yearling ocean entrants to return as jacks (Table 3). Eighty-seven percent of the fish with a subyearling scale pattern returned as full-term adults (II-, III-, and IV-salts) compared to 68% for fish with a yearling scale pattern. Of the 88 full-term adults, 36% had entered the ocean as subyearlings and 64% as yearlings.

Table 3. Number of years spent in seawater by adult fall Chinook salmon (wild $n = 21$; hatchery $n = 99$) PIT tagged as subyearlings in the Snake and Clearwater Rivers for life history/survival studies (1994-2004). All fish migrated inriver as juveniles. Mini-jacks spent less than 1 year in seawater.

				Full-term adults		
		Mini-jack	I-salt	II-salt	III-salt	IV-salt
Age at ocean entry	N	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Age-0	37	0 (0)	5 (14)	18 (49)	14 (38)	0 (0)
Age-1	83	8 (10)	19 (23)	26 (31)	29 (35)	1 (1)

Size at Return

For fish from the Snake and Clearwater Rivers combined, mean fork length at return increased with time spent in seawater (Figure 2). Within each seawater class, returning adults that had entered the ocean as subyearlings were smaller as adults than those that had entered the ocean as yearlings (Figure 2). Full-term adult females that had entered the ocean as subyearlings averaged 75 ± 10 cm (SD; $n = 11$) compared to full-term adult females that had entered the ocean as yearlings at 78 ± 7 cm (SD; $n = 28$). Full-term adult males that had entered the ocean as subyearlings averaged 72 ± 13 cm (SD; $n = 13$) compared to full-term adult males that had entered the ocean as yearlings at 83 ± 16 cm (SD; $n = 14$).

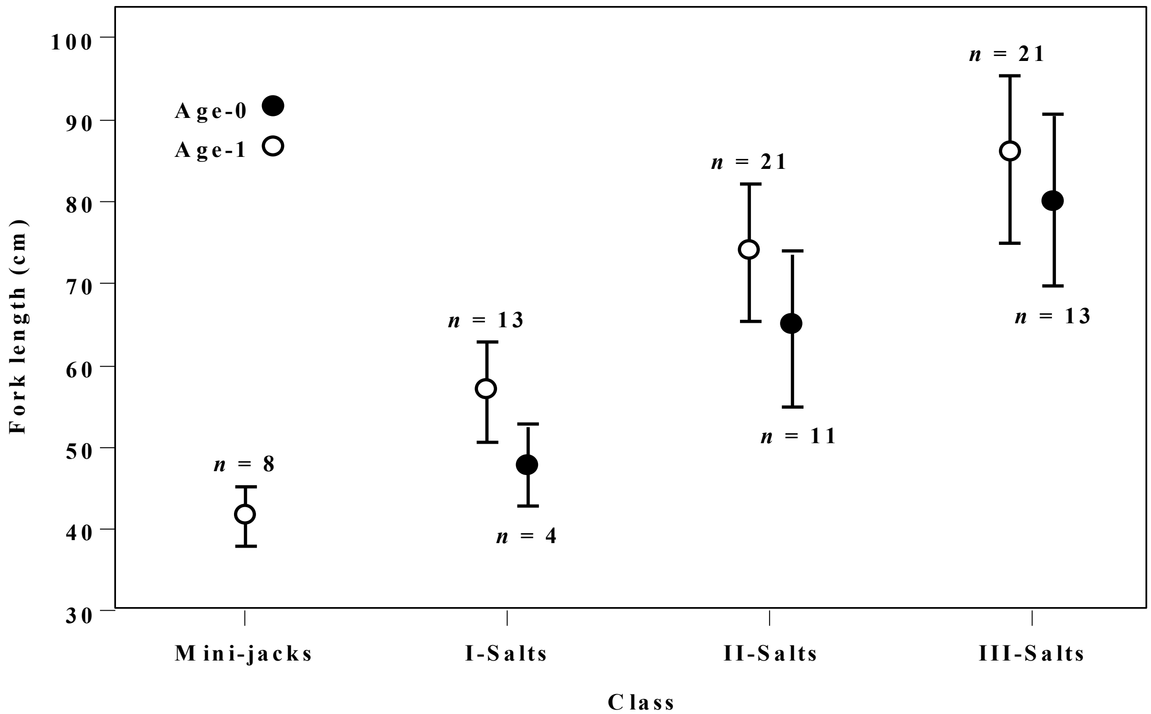

Figure 2. Mean fork length (cm) of adult fall Chinook salmon PIT tagged as subyearlings for juvenile life history/survival studies (1994-2004). These fish migrated inriver and entered the ocean as subyearlings (age-0, black circle) or yearlings (age-1, open circle). Data are from Snake and Clearwater River fish combined (wild *n* = 16; hatchery *n* = 75). Whiskers indicate SD. Fork length was not plotted for the single IV-salt that had been a yearling ocean entrant.

Transportation Studies: Returns from Releases in 2001-2004

During 2005 and 2006, we collected readable scale samples at Lower Granite Dam from 72 adult fall Chinook salmon released as subyearlings for Snake River transportation studies (2001-2004). Thirty-seven of these adults had been transported during summer or fall and released below Bonneville Dam (Table 4). Of the 31 adults transported as juveniles during summer, 74% had entered the ocean as subyearlings and 26% as yearlings after wintering in fresh or estuarine water downstream from Bonneville Dam. Of the 6 adults transported as juveniles during fall, 17% had entered the ocean as subyearlings and 83% as yearlings after wintering in fresh or estuarine water downstream from Bonneville Dam.

Thirty-five of the 72 returning adults from transport studies had migrated inriver as juveniles (Table 4). Yearling ocean entrants that had wintered in unknown freshwater/estuarine locations were predominant, making up 43% of the adults. First-year wintering location percentages calculated across years were 23% seawater, 34% reservoir, and 43% unknown freshwater/estuarine. Inriver migrants that spent their first winter in seawater were usually detected for the last time in summer (Table 4). Of the 13 inriver migrants that entered the ocean without ever being detected, 13% spent their first winter in seawater, while 87% spent their first winter in unknown freshwater/estuarine locations.

Table 4. Migration pathway, age at ocean entry, and first-year wintering location of adult fall Chinook salmon PIT-tagged and released into the Snake River as subyearlings for transport studies (wild n = 1; hatchery n = 70; unconfirmed n = 1). Fresh/estuary = fresh water/estuary below Bonneville Dam.

			Last juvenile detection			
Age at ocean entry	First-year winter location	Intra-pathway composition N (%)	Summer (21 Jun-31 Aug) n (%)	Fall (1 Sep-10 Dec) n (%)	Spring (year t + 1) n (%)	Never detected n (%)
Summer Transport						
Age-0	Seawater	23 (74)	23 (100)			
Age-1	Fresh/estuary	8 (26)	8 (100)			
Fall Transport						
Age-0	Seawater	1 (40)		1 (100)		
Age-1	Fresh/estuary	5 (60)		5 (100)		
Inriver Migrant						
Age-0	Seawater	8 (23)	6 (75)	1 (13)		1 (13)
Age-1	Reservoir	12 (34)			12 (100)	
Age-1	Unknown	15 (43)	1 (7)	1 (7)		13 (87)

Time in Seawater

For fall Chinook from all migrational pathways combined, time spent in seawater ranged from 1 to 4 years for fish that entered the ocean as subyearlings and from less than 1 year to 3 years for fish that entered as yearlings (Table 5). Subyearling ocean entrants did not return as mini-jacks, and jack returns were similar for both yearling and subyearling ocean entrants. Eighty-eight percent of fish with a subyearling scale pattern returned as full-term adults (II-, III-, and IV-salts) compared to 80% of fish with a yearling scale pattern. Of the 60 full-term adults, 53% had entered the ocean as subyearlings and 47% as yearlings.

Table 5. Number of years spent in seawater by adult fall Chinook salmon (wild n = 1; hatchery n = 70; unconfirmed n = 1) PIT-tagged during 2001-2004 for transport studies and recaptured at Lower Granite Dam (2005 and 2006). Data is for spring- and summer-transported fish and inriver migrants combined. Mini-jacks spent less than 1 year in seawater.

				Full-term adults		
Age at ocean entry	N	Mini-jack *n* (%)	I-salt *n* (%)	II-salt *n* (%)	III-salt *n* (%)	IV-salt *n* (%)
Age-0	32	0 (0)	4 (13)	14 (44)	10 (31)	4 (13)
Age-1	40	3 (8)	5 (13)	22 (55)	10 (25)	0 (0)

Size at Return

For analysis of size at return, data were pooled for transported and inriver migrant fall Chinook salmon. Mean fork length at return increased with time spent in seawater (Figure 3). Within each seawater class, adults that had entered the ocean as subyearlings were smaller as adults than those that had entered the ocean as yearlings, but the difference in size diminished with time spent in seawater. Full-term adult females that had entered the ocean as subyearlings were larger on average (78 $\pm$ 5 cm SD; n = 9) than full-term female adults that had entered the ocean as yearlings (75 $\pm$ 8 cm SD; n = 23) because three of the full-term adult females that had been subyearling ocean entrants returned as IV-salts, whereas none of full-term adult females that had been yearling ocean entrant returned as IV-salts. Full-term adult males that had entered the ocean as subyearlings averaged 69 $\pm$ 6 cm (SD; n = 19) compared to full-term adult males that had entered the ocean as yearlings at 69 $\pm$ 9 cm (SD; n = 9).

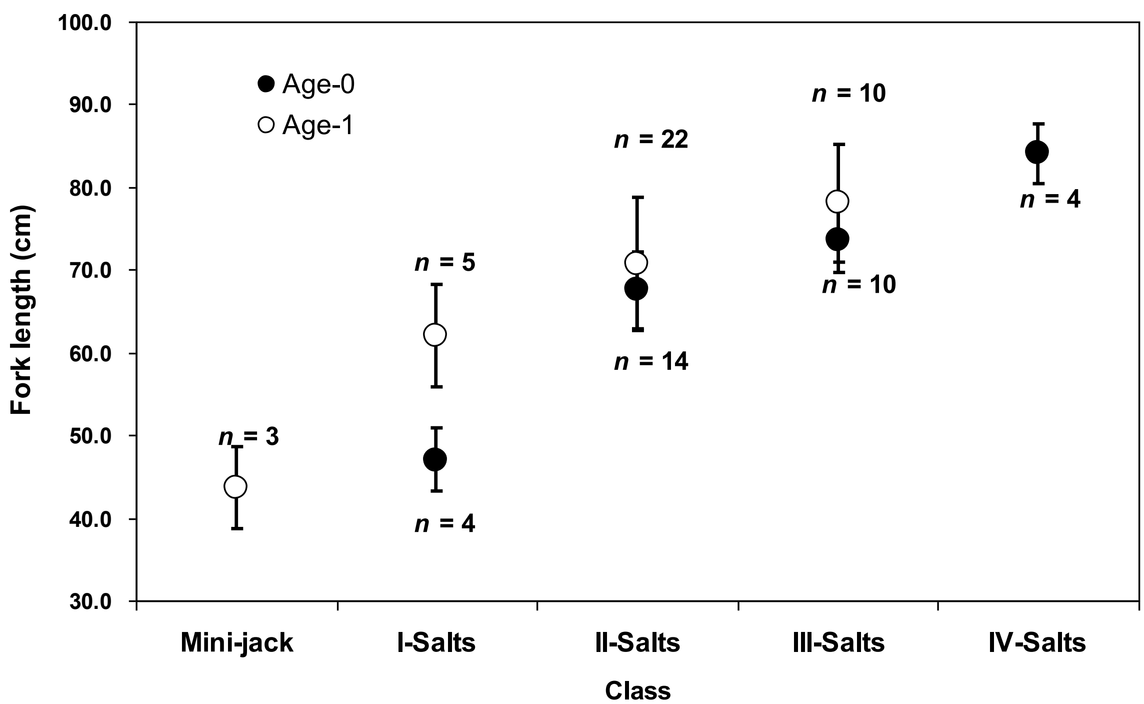

Figure 3. Mean fork length (cm $\pm$ SD) of fall Chinook salmon (wild n = 1; hatchery n = 70; unconfirmed n = 1) that were PIT-tagged during 2001-2004 transport studies. Fish were either transported or migrated inriver, entered the ocean as subyearlings (age-0, black circles) or yearlings (age-1, open circles), and were then recaptured and measured at Lower Granite Dam when returning to spawn in 2005 and 2006.

Dam Passage Strategy Study: Returns from 2005

Snake River Fall Chinook Salmon

During 2006, we recaptured 41 adults PIT-tagged and released to the Snake River as subyearlings for a dam-passage strategy study in 2005. Two fish, a jack and a mini-jack, had been transported in 2005 (older returning adults expected in 2007 through 2010). The jack had been transported during summer and had entered the ocean as a subyearling, whereas the mini-jack had been transported during fall and had entered the ocean as a yearling (Table 6).

Of the remaining 39 recaptured fish, 34 were jacks and 5 were mini-jacks that had migrated inriver after release as juveniles in 2005. Jacks that had been subyearling ocean entrants were predominant, making up 87% of the sample (Table 6). The remaining 13% of the sample was made up of mini-jacks that entered seawater as yearlings after wintering in unknown freshwater/estuarine locations. Inriver migrants that spent their first winter in seawater were either last detected during summer (44%) or never detected (56%; Table 6). No yearling ocean entrants were known to have wintered in reservoirs. Five yearling ocean entrants that had wintered in unknown freshwater/estuary locations were never detected as juveniles.

Table 6. Migration pathway, age at ocean entry, and first-year wintering location for fall Chinook salmon PIT-tagged for a dam passage strategy study and released into the Snake River as subyearlings in 2005 (wild n = 5; hatchery n = 36) . Fresh/estuary = fresh water/estuary downstream from Bonneville Dam.

			Last juvenile detection			
Age at ocean entry	First-year wintering location	Intra-pathway composition N (%)	Summer (21 Jun-31 Aug) n (%)	Fall (1 Sep-10 Dec) n (%)	Spring (year t + 1) n (%)	Never detected n (%)
Summer transport						
Age-0	Seawater	1 (100)	1 (100)			
Age-1	Fresh/estuary	0 (0)				
Fall transport						
Age-0	Seawater	0 (0)				
Age-1	Fresh/estuary	1 (100)		1 (100)		
Inriver						
Age-0	Seawater	34 (87)	15 (44)			19 (56)
Age-1	Reservoir	0 (0)				
Age-1	Unknown	5 (13)				5 (100)

Clearwater River Fall Chinook Salmon

During 2006, we recaptured 23 adults PIT-tagged and released to the Clearwater River as subyearlings for a dam-passage strategy study in 2005. These included 2 jacks and 8 mini-jacks that had been transported as subyearlings in 2005. Both jacks had been transported in summer and had entered the ocean as subyearlings, whereas all eight mini-jacks had been transported in fall and wintered in fresh or estuarine water downstream from Bonneville Dam (Table 7).

We recaptured 2 jacks and 14 mini-jacks that had migrated inriver as juveniles after release into the Clearwater River in 2005. Mini-jacks that had been yearling ocean entrants and had wintered in unknown freshwater/estuary locations were predominant, making up 56% of the sample (Table 7). The remainder of the sample was made up of mini-jacks that had entered seawater as yearlings after wintering in reservoirs (31%) and jacks that had entered seawater as subyearlings (13%).

The two inriver migrants that spent their first winter in seawater had never been detected as juveniles (Table 7). Sixty-seven percent of the inriver migrants that had spent their first winter in unknown freshwater/estuarine locations were never detected as juveniles. The remaining 33% of the inriver migrants that had spent their first winter in unknown freshwater locations were last detected in the fall.

Table 7. Migration pathway, age at ocean entry, and first-year wintering location of adult hatchery fall Chinook salmon PIT-tagged as subyearlings and released into the Clearwater River for a 2005 study of dam passage strategies (n = 26) . Fish were recaptured at Lower Granite Dam when returning to spawn in 2006. Fresh/estuary = fresh water/estuary below Bonneville Dam.

			Last juvenile detection			
Age at ocean entry	First-year wintering location	Intra-pathway composition N (%)	Summer (21 Jun-31 Aug) *n* (%)	Fall (1 Sep-10 Dec) *n* (%)	Spring (year t + 1) *n* (%)	Never detected *n* (%)
Summer transport						
Age-0	Seawater	2 (100)	2 (100)			
Age-1	Fresh/estuary	0 (0)				
Fall transport						
Age-0	Seawater	0 (0)				
Age-1	Fresh/estuary	8 (100)		8 (100)		
Inriver						
Age-0	Seawater	2 (13)				2 (100)
Age-1	Reservoir	2 (31)			5 (100)	
Age-1	Unknown	9 (56)		3 (33)		6 (67)

Returns from Supplemental Fall Transport Tagging

During 2005 and 2006, we recaptured 80 returning adults that had been tagged as juveniles at Lower Granite Dam during September and October of 2002-2005 (Table 8). These fish were tagged to supplement the number of PIT-tagged subyearlings transported in fall because few of these fish released in May and June were being transported during fall. River-run juveniles collected from the juvenile fish facility daily sample were tagged and transported by truck to below Bonneville Dam along with the general collection.

Table 8. Age at ocean entry and first-year winter location of adult river-run fall Chinook salmon tagged as subyearlings to supplement fall transport studies in 2002-2005 (wild n = 40, hatchery n = 39, and unconfirmed n = 1). All fish were fall transports; Fresh/estuary = fresh water/estuary below Bonneville Dam.

			Last juvenile detection			
Age at ocean entry	First-year wintering location	Intra-pathway composition N (%)	Summer (21 Jun-31 Aug) *n* (%)	Fall (1 Sep-10 Dec) *n* (%)	Spring (year $t + 1$) *n* (%)	Never detected *n* (%)
Age-0	Seawater	29 (36)		29 (100)		
Age-1	Fresh/estuary	51 (64)		51 (100)		

Of the 80 adults recaptured, 29 had entered the ocean as subyearlings and 51 as yearlings. Subyearling ocean entrants were jacks (17%), II-salt (34%), III-salt (38%), and IV-salt adults (10%, Table 9). Yearling ocean entrants ranged from mini-jacks to III-salt adults. Mini-jacks, I-salt, and II-salt adults each comprised approximately 30% of the return with IV-salt adults comprising the final 10%. Origins of these fish were 39 hatchery, 40 wild, and one undetermined.

Table 9. Years spent in seawater by river-run fall Chinook salmon PIT-tagged as subyearlings for supplemental fall transport 2002-2005 (wild n = 40, hatchery n = 39, and unconfirmed n = 1). Fish entered the ocean as subyearlings (age-0) or yearlings (age-1). Mini-jacks spent less than 1 year in seawater.

				Full-term adults		
Age at ocean entry	N	Mini-jacks *n* (%)	I-salts *n* (%)	II-salts *n* (%)	III-salts *n* (%)	IV-salts *n* (%)
Age-0	29	0 (0)	5 (17)	10 (34)	11 (38)	3 (10)
Age-1	51	15 (29)	15 (29)	16 (31)	5 (10)	0 (0)

Mean fork length at return increased with time spent in seawater (Figure 4). Within each seawater class, adults that had entered the ocean as subyearlings were smaller as adults than those that had entered the ocean as yearlings, but the difference in size diminished with time spent in seawater. Full-term adult females that had entered the ocean as subyearlings were larger on average (84 $\pm$ 7 cm SD; n = 5) than full-term female adults that had entered the ocean as yearlings (80 $\pm$ 4 cm SD; n = 12). This larger average size occurred because two of the full-term adult females that had been subyearling ocean entrants returned as IV-salts, whereas none of full-term adult females that had been yearling ocean entrant returned as IV-salts. Full-term adult males that had entered the ocean as subyearlings averaged 72 $\pm$ 11 cm (SD; n = 18) compared to full-term adult males that had entered the ocean as yearlings at 78 $\pm$ 9 cm (SD; n = 9).

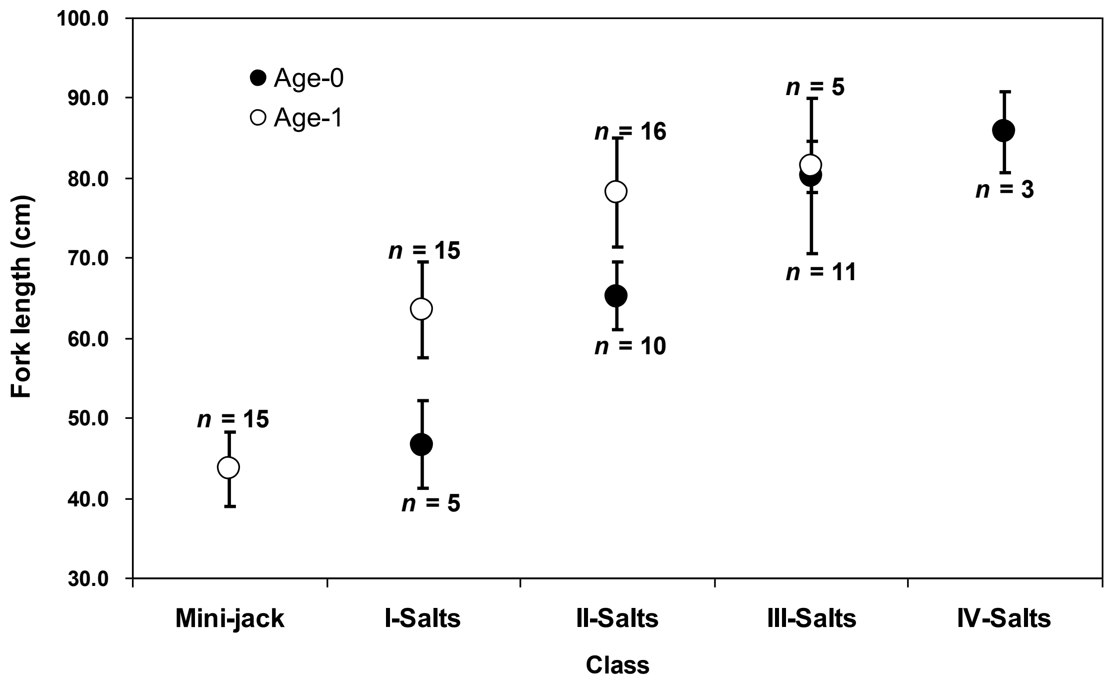

Figure 4. Mean fork length (cm $\pm$ SD) of river-run fall Chinook salmon (wild n = 40, hatchery n = 39, and unconfirmed n = 1) that were PIT-tagged as subyearlings at Lower Granite Dam in September and October 2002-2005 and transported to below Bonneville Dam. Fish entered the ocean as subyearlings (age-0, black circles) or yearlings (age-1, open circles), and were then recaptured and measured at Lower Granite Dam when returning to spawn in 2005 and 2006.

DISCUSSION

As was the case during the first year of this study, sample sizes of returning PIT-tagged adults in 2006 remained limited. Therefore, for the second year, we pooled data for analyses across release years, return years, and seawater age classes, and between origins, genders, and rivers. Complete data for all adult returns to date is provided in Appendix Table 1. We plan to continue recapture of returning adults at Lower Granite Dam for several more years. This will make it possible to more fully represent the entire population. Acknowledging the sample size limitation, we focus our discussion on a second year of preliminary observations. We emphasize that our conclusions are tentative and might change in the future as additional data are collected.

We analyzed data from a total of 134 returning fall Chinook salmon recaptured at Lower Granite Dam during 1998-2006. These adults had been PIT tagged as subyearlings and released to migrate inriver as part of juvenile life history/survival and transport studies during 1994-1998 and 2000-2004, when summer spill was limited at Snake River dams. Of the 134 adults, only 32 (24%) had entered the ocean as subyearlings, and only 6 of these 32 fish had never been detected as juveniles. The remaining 102 (76%) adults had entered the ocean as yearlings, and 31 of these were known to have spent their first winter in reservoirs. The remaining 71 adults had wintered in unknown freshwater/estuarine locations, but two lines of evidence suggest that many of them likely wintered in reservoirs upstream from Bonneville Dam.

First, of these 71 adults, 31 had been detected as juveniles upstream from Bonneville Dam, and 20 of these detections had occurred in fall. It is unlikely that many fish detected upstream from Bonneville Dam in fall subsequently passed all remaining dams, including Bonneville, before winter. This is because migrational disposition tends to decrease later in the migration season (Connor et al. 2003),

The second line of evidence applies to the remaining 40 yearling ocean entrants that were never detected as juveniles. Summer spill was limited at Snake River dams during the years when these subyearlings were released. During these years of limited spill, survival probability from Lower Granite Reservoir to the tailrace of Lower Monumental Dam was estimated at 7% or less for a non-detected PIT-tagged subyearling that was actively migrating (Appendix Table 2). Though data are not available to estimate survival probability through the entire river from Lower Granite Reservoir to Bonneville Dam tailrace, it would be lower than 7% for a non-detected fish because additional detections would likely occur at McNary, John Day, and Bonneville Dams.

The fall Chinook salmon adults we recaptured that migrated inriver during migration years 1994-2004 as part of life history/survival studies provided baseline data for non-summer spill years, whereas the fall Chinook salmon jacks and mini-jacks we recaptured that migrated inriver during migration year 2005 as part of the study on dam passage strategies provided the first baseline data for summer spill years. Three trends in the results for inriver migrants have been observed in fish from both the Snake and Clearwater Rivers. These trends should be followed as more data become available.

For adult inriver migrants from the Snake River, the following trends were observed:

1) The percentage of adults that had been yearling ocean entrants decreased from 76% for the 1998-2004 releases to 13% for the 2005 releases.
2) The percentage of adults that had been reservoir-type juveniles decreased from 22% or more for the 1998-2004 releases to 0% or more for the 2005 releases.
3) Fewer subyearling ocean entrants passed downstream undetected during 1998-2004 than in 2005.

It could be argued that trends 1 and 2 were explained by summer spill in 2005, which enabled many juveniles to enter the ocean as subyearling when they would otherwise have wintered in reservoirs and entered the ocean as yearlings. However, this conclusion is confounded by another trend found within years of limited spill for wild PIT-tagged fish released as subyearlings and known to have wintered in Snake River reservoirs. Proportions of these fish were already declining prior to 2005, and had dropped from 25% in migration year 1994 to 0.3% in migration year 2004 (Connor et al. 2002, unpublished data). In the case of trend 3 above, summer spill undoubtedly increased the percentage of subyearling ocean entrants that passed to the sea undetected.

The following three trends were observed in returning inriver-migrant adults from the Clearwater River:

1) The percentage of adults that had been yearling ocean entrants varied little between the 1998-2004 (82%) and 2005 releases (88%).
2) The percentage of adults that had been reservoir-type juveniles varied little between fished released during 1998-2004 (36% or more) and those released in 2005 (31% or more).
3) Fewer subyearling ocean entrants passed downstream undetected during 1998-2004 than in 2005.

Trends 1 and 2 suggest that contrary to what would be expected, the use of spill to augment fish passage in summer 2005 did not decrease the percentage of Clearwater River subyearlings that wintered in reservoirs and entered the ocean as yearlings. We know of two plausible explanations for this finding. First, for Clearwater River wild and surrogate† subyearlings, Connor et al. (2007) estimated minimum survival probabilities of 61-68% to Lower Granite, 50-65% to Little Goose, and 73-89% to Lower Monumental Dam. However, in each of these estimates, large percentages of fish did not pass Snake River dams until fall 2005, after summer flow augmentation had ended. Second, excessive forebay delay (a primary justification for summer spill) might not be a factor affecting the reservoir-type life history. Trend 3 suggests that, as with Snake River fish, summer spill undoubtedly increased the percentage of Clearwater River subyearling ocean entrants that passed to the sea undetected.

Fall Chinook adults that had been transported as subyearlings and returned to Lower Granite Dam in 2005-2006 had entered the ocean as both subyearlings and yearlings. This confirmed that transported subyearlings do winter in fresh or estuarine waters below Bonneville Dam. Though we expected to see this in some transported subyearlings, the actual number observed was much larger than expected, especially in the supplemental fall transport group.

The difference in patterns of age at ocean entry between fish that were transported in summer vs. fall was consistent with a late-season decrease in migrational disposition. Fish transported in summer were mostly actively migrating, ocean-type juveniles that continued seaward movement after transport. Conversely, fish transported in fall may have been collected at a dam while moving downstream in search of an eventual wintering location. This juvenile life-history strategy has been observed for subyearling spring Chinook salmon produced in headwater streams (e.g., Chapman and Bjornn 1969; Bjornn 1971).

In adults from the supplemental fall transport study, there was a difference in the ratio of age at ocean entry between river-run and surrogate-sized fish. Surrogates were tagged and released above Lower Granite Dam and subsequently collected and transported in fall. River-run fish were collected at the dam, tagged, and transported in fall (September and October). Of all returning adults from supplemental fall transport studies, only 7% (1 of 15) of surrogate fish entered the ocean as subyearlings, while 36% (29 of 80) of river-run fish did so.

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† Surrogates differ from production hatchery fish in that they are raised to be released at the size of smaller, wild subyearling Chinook salmon.

Some of this difference might be due to the small number of returns from surrogate fish released above Lower Granite Dam. However, the difference may also be related to the timing of fall transports. To evaluate this possibility, we examined within-season timing of subyearling vs. yearling ocean entrants among river-run fall transport fish tagged at Lower Granite Dam (Figure 5). We found that returning adults transported as juveniles in September had a ratio of 63 subyearling to 34 yearling ocean entrants, while the ratio for those transported in October was 26 to 74. For adults transported as juveniles during the last 2 weeks of October, the ratio was 12 subyearling to 88 yearling ocean entrants.

We found that for adult fall Chinook salmon from the life history/survival and transport studies, time spent in seawater was dependent on age at ocean entry. Subyearling ocean entrants were less likely to return after spending a year or less at sea than yearling ocean entrants. Yearling ocean entrants produced more jacks and mini-jacks than subyearling ocean entrants; however, they still made up more than half of the full-term adults recaptured at Lower Granite Dam (103 of 193).

Based on data from the first year of this study, we reported that for full-term adults, the size (FL) of yearling ocean entrants was similar to or larger than that of subyearling ocean entrants (Marsh et al. 2007). We felt this finding provided a different perspective on the effects of juvenile life history than that of previous size comparisons by total age (i.e., return year minus brood year; e.g., Connor et al. 2005; Milks et al. 2006). We also concluded that analyses conducted on total age are inadequate in that they fail to capture the fact that yearling ocean entry does not result in a reduction of body size of full-term adults and that body size, not age, is the factor that most influences stock productivity.

After adding data collected in 2006 to our analysis, these conclusions held true for inriver migrants from the life history/survival group. However, for full-term transported adult females, fish that had been subyearlings at ocean entry were larger on average than those that had been yearlings at ocean entry. However, among the transported subyearling ocean entrants, 44% were IV-salts, while among the transported yearling ocean entrants, none were IV-salts. Thus, the observed size difference may or may not persist in 2007, when fork-length data will be available for IV-salt transported females that entered the ocean as yearlings.

In conclusion, results from our study to date show clearly that Snake River basin fall Chinook salmon employ diverse downstream passage and life history strategies to reach the ocean. These strategies need to be considered when designing studies to assess dam passage strategies and experiences (Marsh and Connor 2004; Schaller et al. 2007).

Results from 2006 show conclusively that transported juveniles do overwinter in fresh or estuarine water below Bonneville Dam, in contrast to earlier assumptions (Connor et al. 2005). However, results continued to support the idea that overwintering in reservoirs and entering the ocean as a yearling is a productive downstream passage strategy for Snake River Basin fall Chinook salmon. This strategy appears to be productive during years of limited spill and during years when spill is fully implemented. Our findings also underscore the importance of understanding the migration history of all returning adults and the difficulty in attempting to make unbiased SAR estimates for non-detected inriver migrant groups, especially those from the Clearwater River.

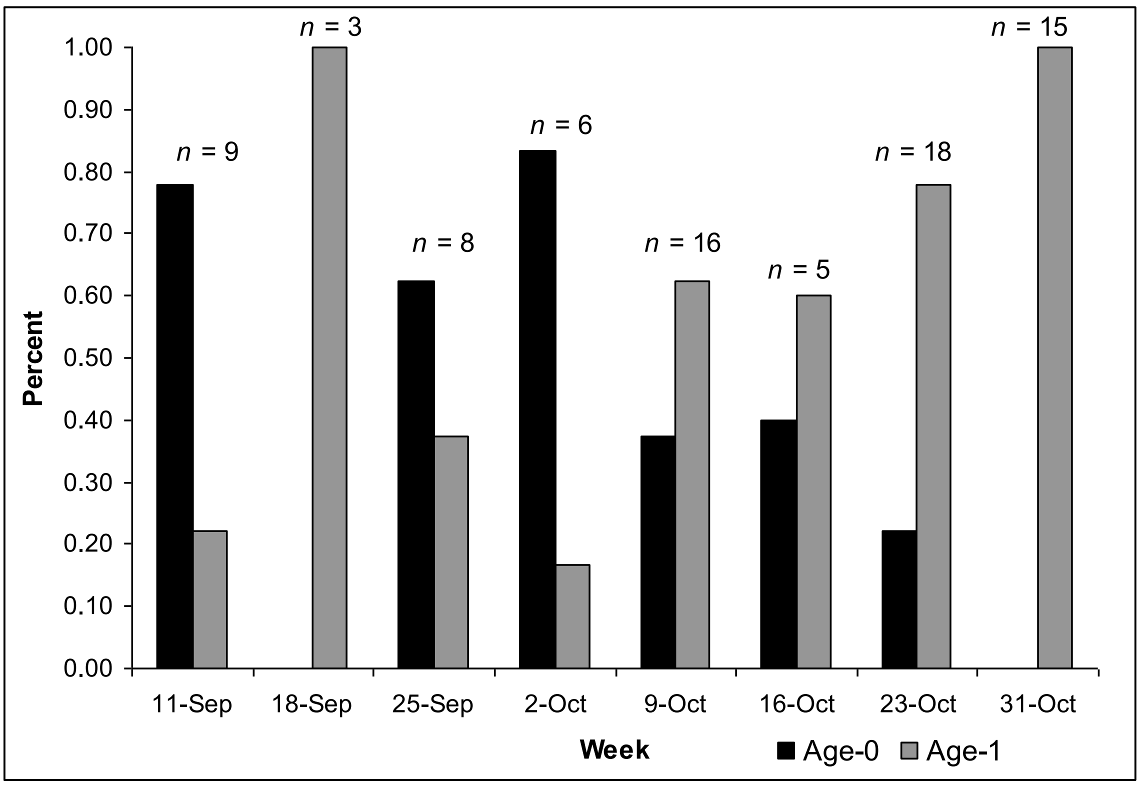

Figure 5 Percentages of subyearling (Age-0) and yearling (Age-1) ocean entrants based on the date the returning adults had been tagged at Lower Granite Dam and transported by truck to below Bonneville Dam during fall 2002-2005. Dates were grouped in weekly blocks and *n* is the total number of returning adults that had been tagged that week.

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REFERENCES

Buchanan, R. A. and J. R. Skalski. 2006. Design and analysis of salmonid tagging studies in the Columbia Basin, volume XIX. Report of the University of Washington School of Aquatic and Fishery Sciences to the Bonneville Power Administration, Portland, Oregon.

Bjornn, T. C. 1971. Trout and salmon movement in two streams as related to temperature, food, stream flow, cover, and population density. Transactions of the American Fisheries Society 100:423-438.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmonids in streams with special reference to food and feeding. Pages 153-176 in T. G. Northcote, editor. Symposium on salmon and trout streams. University of British Columbia, Vancouver.

Connor, W. P., H. L. Burge, R. Waitt, and T. C. Bjornn. 2002. Juvenile life history of wild fall Chinook salmon in the Snake and Clearwater rivers. North American Journal of Fisheries Management 22:703-712.

Connor, W. P., R. K. Steinhorst, and H. L. Burge. 2003. Migrational behavior and seaward movement of wild subyearling fall Chinook salmon in the Snake River. North American Journal of Fisheries Management 23:414-430.

Connor, W. P., J. G. Sneva, K. F. Tiffan, R. K. Steinhorst, D. Ross. 2005. Two alternative juvenile life histories for fall Chinook salmon in the Snake River basin. Transactions of the American Fisheries Society 134:291-304.

Connor, W. P., B. D. Arnsberg, S. G. Smith, D. M. Marsh, and W. D. Muir. 2007. Post-release performance of natural and hatchery subyearling fall Chinook salmon in the Snake and Clearwater Rivers. Report of the U. S. Fish and Wildlife Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Downing, S. L., E. F. Prentice, R. W. Frazier, J. E. Simonson, E. P. Nunnallee. 2001. Technology developed for diverting passive integrated transponder (PIT) tagged fish at hydroelectric dams in the Columbia River Basin. Aquacultural Engineering, 25:149-164.

Harmon, J. R. 2003. A trap for handling adult anadromous salmonids at Lower Granite Dam on the Snake River, Washington. North American Journal of Fisheries Management 23:989-992.

Healey, M. C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pages 312 to 393 *in* C. Groot and L. Margolis, editors, Pacific salmon life histories. UBC press, Vancouver, British Columbia.

Marsh, D. M., and W. P. Connor. 2004c. A study to compare SARs of Snake River fall Chinook salmon under alternative transportation and dam operational strategies. Proposal to the U.S. Army Corps of Engineers, Wall Walla District, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, W. D. Muir, and W. P. Connor. 2007. A study to understand the early life history of Snake River fall Chinook salmon. Report to U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2003. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 2001. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2004a. Transportation of juvenile salmonids on the Columbia and Snake Rivers, 2003: Final report for 2000 and 2001 steelhead juveniles. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2004b. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 2002. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, G. M. Matthews, and W. D. Muir. 2005. Transportation of juvenile salmonids on the Columbia and Snake Rivers, 2004: Final report for 2002 steelhead juveniles. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., G. M. Matthews, S. Achord, T. E. Ruehle, and B. P. Sandford. 1999. Diversion of salmonid smolts tagged with passive integrated transponders from an untagged population passing through a juvenile collection system. North American Journal of Fisheries Management 19:1142-1146.

Milks, D., M. Varney, J. Jording, and M. Schuck.. 2006. Lyons Ferry Hatchery evaluation fall Chinook salmon. 2003 and 2004 annual report to the U. S. Fish and Wildlife Service Lower Snake River Compensation Plan Office, Boise, Idaho.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1990a. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. American Fisheries Society Symposium 7:317-322.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, and D. F. Brastow. 1990b. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. American Fisheries Society Symposium 7:323-334.

Sandford, B. P., and S. G. Smith. 2002. Estimation of smolt-to-adult return percentages for Snake River Basin anadromous salmonids, 1990-1997. Journal of Agricultural Biological, and Environmental Statistics 7:243-263.

Schaller, H. and thirteen co-authors. 2007. Comparative Survival Study (CSS) of PIT-tagged spring/summer Chinook and steelhead in the Columbia River Basin: Ten-year retrospective summary report. Bonneville Power Administration contracts 1994-033-00 and 1996-020-00.

Smith, S. G., W. D. Muir, E. E. Hockersmith, R.W. Zabel, R. J. Graves, C. V. Ross, W. P. Connor, and B. D. Arnsberg. 2003. Influence of river conditions on survival and travel time of Snake River subyearling fall Chinook salmon. North American Journal of Fisheries Management 23: 939-961.

Tiffan, K. F., and W. P. Connor. 2005. Investigating passage of ESA-listed juvenile fall Chinook salmon at Lower Granite Dam during winter when the fish bypass system is not operated. 2004 Annual report to the Bonneville Power Administration, Project 200203200.

Zimmerman, C. E., R. W. Stonecypher, Jr., and M. C. Hayes. 2003. Migration o precocious male hatchery Chinook salmon in the Umatilla River, Oregon. North American Journal of Fisheries Management 23:1006-1014.

APPENDIX

Data Summary Tables

Appendix Table 1. Data on adult fall Chinook salmon PIT tagged as subyearlings as part of juvenile Life History/Survival, Transport, and Dam Passage Strategy studies. Ocean age is time spent in seawater, Transport-S is summer transport, Transport-F is fall transport, LGR is Lower Granite Dam, ND is never detected.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Life History/Survival Studies										
Inriver	1994	Snake R	Spring	Reservoir	1998	Female	Wild	1	3	83
Inriver	1995	Snake R	ND	Unknown	1999	Female	Hatchery	1	3	
Inriver	1995	Snake R	ND	Unknown	1999	Female	Hatchery	1	3	90
Inriver	1995	Snake R	ND	Unknown	1999	Male	Hatchery	1	3	77
Inriver	1995	Snake R	Fall	Unknown	1999	Male	Hatchery	1	3	
Inriver	1995	Snake R	Fall	Unknown	1999	Male	Hatchery	1	3	76
Inriver	1995	Snake R	Summer	Unknown	1999	Male	Hatchery	1	3	104
Inriver	1995	Snake R	Fall	Unknown	1999	Female	Hatchery	1	3	78
Inriver	1995	Snake R	ND	Unknown	1998	Female	Wild	1	2	80
Inriver	1995	Snake R	Fall	Unknown	1999	Female	Hatchery	1	3	73
Inriver	1995	Snake R	ND	Unknown	1999		Hatchery	1	3	
Inriver	1995	Snake R	Fall	Unknown	1999	Male	Hatchery	1	3	99
Inriver	1995	Snake R	Fall	Unknown	1999	Male	Wild	1	3	72
Inriver	1995	Snake R	ND	Unknown	1999	Female	Hatchery	1	3	84
Inriver	1995	Snake R	ND	Unknown	1998	Female	Hatchery	1	2	78
Inriver	1995	Snake R	Summer	Seawater	1998	Female	Hatchery	0	3	90
Inriver	1995	Snake R	ND	Unknown	1999	Male	Hatchery	1	3	
Inriver	1995	Snake R	Fall	Unknown	1998	Female	Hatchery	1	2	84
Inriver	1995	Snake R	Fall	Unknown	1999	Female	Hatchery	1	3	90
Inriver	1995	Snake R	Summer	Seawater	1998	Female	Hatchery	0	3	81
Inriver	1995	Snake R	ND	Unknown	1999	Male	Wild	1	3	102
Inriver	1995	Snake R	Summer	Unknown	1999	Male	Hatchery	1	3	100
Inriver	1995	Snake R	Fall	Unknown	1998	Female	Hatchery	1	2	72
Inriver	1995	Snake R	Fall	Unknown	1998	Female	Hatchery	1	2	77
Inriver	1995	Snake R	Fall	Unknown	1999		Hatchery	1	3	
Inriver	1995	Snake R	Fall	Unknown	1999	Male	Hatchery	1	3	

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Life History/Survival Studies (Continued)										
Inriver	1995	Snake R	ND	Unknown	1998	Female	Hatchery	1	2	76
Inriver	1995	Snake R	ND	Unknown	1999	Female	Hatchery	1	3	82
Inriver	1995	Snake R	Fall	Unknown	1999		Hatchery	1	3	
Inriver	1995	Snake R	Fall	Unknown	1998	Female	Hatchery	1	2	70
Inriver	1995	Snake R	ND	Unknown	1998	Female	Hatchery	1	2	74
Inriver	1996	Clearwater R	Summer	Seawater	1999	Female	Hatchery	0	3	76
Inriver	1996	Snake R	ND	Unknown	2000	Male	Hatchery	1	3	82
Inriver	1996	Clearwater R	Fall	Unknown	2000	Male	Hatchery	1	3	87
Inriver	1996	Snake R	ND	Unknown	2000	Female	Hatchery	1	3	78
Inriver	1996	Clearwater R	ND	Unknown	2000	Female	Hatchery	1	3	87
Inriver	1996	Snake R	Summer	Unknown	1999	Female	Hatchery	1	2	78
Inriver	1996	Snake R	Spring	Reservoir	1999	Female	Hatchery	1	2	67
Inriver	1996	Clearwater R	ND	Unknown	2000	Female	Hatchery	1	3	81
Inriver	1996	Snake R	Fall	Seawater	1999	Female	Hatchery	0	3	58
Inriver	1997	Snake R	Spring	Reservoir	2000	Male	Hatchery	1	2	71
Inriver	1997	Snake R	Spring	Reservoir	2000	Female	Hatchery	1	2	75
Inriver	1997	Clearwater R	ND	Unknown	2000	Female	Hatchery	1	2	
Inriver	1997	Snake R	Spring	Reservoir	2001		Hatchery	1	3	
Inriver	1997	Snake R	ND	Seawater	1999	Male	Hatchery	0	2	
Inriver	1997	Snake R	Fall	Unknown	2000	Male	Wild	1	2	67
Inriver	1997	Snake R	Spring	Reservoir	2000	Male	Hatchery	1	2	51
Inriver	1997	Snake R	Spring	Reservoir	2000	Female	Wild	1	2	87
Inriver	1997	Snake R	Summer	Unknown	2000		Hatchery	1	2	75
Inriver	1997	Snake R	ND	Unknown	2000	Female	Hatchery	1	2	80
Inriver	1997	Snake R	Summer	Seawater	1999	Female	Hatchery	0	2	66
Inriver	1997	Snake R	Spring	Reservoir	2000	Female	Hatchery	1	2	76
Inriver	1997	Snake R	Summer	Seawater	2000	Male	Hatchery	0	3	75
Inriver	1997	Snake R	Spring	Reservoir	2000	Female	Hatchery	1	2	66

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Life History/Survival Studies (Continued)										
Inriver	1997	Snake R	Summer	Seawater	2000	Female	Hatchery	0	3	77
Inriver	1997	Snake R	Summer	Seawater	2000	Female	Hatchery	0	3	76
Inriver	1997	Snake R	Summer	Seawater	1999	Female	Hatchery	0	2	65
Inriver	1997	Snake R	Fall	Unknown	1999	Female	Hatchery	1	1	61
Inriver	1997	Clearwater R	Spring	Reservoir	2000	Female	Hatchery	1	2	72
Inriver	1998	Clearwater R	Summer	Seawater	2000	Female	Hatchery	0	2	72
Inriver	1998	Snake R	Spring	Reservoir	2001		Hatchery	1	2	
Inriver	1998	Snake R	Summer	Seawater	2000	Male	Hatchery	0	2	60
Inriver	1998	Snake R	ND	Unknown	2002	Female	Hatchery	1	3	87
Inriver	1998	Clearwater R	Spring	Reservoir	2000	Male	Hatchery	1	1	61
Inriver	1998	Snake R	Fall	Unknown	2000	Male	Hatchery	1	1	62
Inriver	1998	Clearwater R	Spring	Reservoir	2000	Male	Hatchery	1	1	57
Inriver	1998	Snake R	Summer	Seawater	1999	Male	Hatchery	0	1	
Inriver	1998	Snake R	Fall	Unknown	2000	Male	Wild	1	1	61
Inriver	1998	Snake R	Summer	Seawater	2001		Hatchery	0	3	
Inriver	1998	Snake R	ND	Seawater	2000	Male	Hatchery	0	2	72
Inriver	1998	Snake R	Summer	Seawater	2000	Male	Hatchery	0	2	66
Inriver	1998	Snake R	Summer	Seawater	2000	Male	Hatchery	0	2	70
Inriver	1998	Snake R	Summer	Unknown	2000	Male	Hatchery	1	1	62
Inriver	1998	Snake R	ND	Seawater	2000	Male	Hatchery	0	2	46
Inriver	1999	Snake R	Summer	Unknown	2001		Hatchery	1	1	
Inriver	1999	Clearwater R	Summer	Seawater	2002	Male	Hatchery	0	3	95
Inriver	1999	Clearwater R	Summer	Unknown	2000	Male	Hatchery	1	0	41
Inriver	1999	Clearwater R	ND	Unknown	2000	Male	Hatchery	1	0	41
Inriver	1999	Snake R	ND	Unknown	2000	Male	Hatchery	1	0	44
Inriver	1999	Snake R	Fall	Seawater	2001		Wild	0	2	
Inriver	1999	Clearwater R	ND	Unknown	2000	Male	Hatchery	1	0	39
Inriver	1999	Clearwater R	ND	Seawater	2000	Male	Hatchery	0	1	44
Inriver	1999	Clearwater R	ND	Unknown	2000	Male	Hatchery	1	0	47

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Life History/Survival Studies (Continued)										
Inriver	1999	Clearwater R	ND	Unknown	2000	Male	Hatchery	1	0	40
Inriver	1999	Snake R	Summer	Seawater	2002	Male	Wild	0	3	80
Inriver	1999	Snake R	Summer	Seawater	2001		Hatchery	0	2	
Inriver	1999	Clearwater R	ND	Seawater	2002	Male	Hatchery	0	3	80
Inriver	1999	Snake R	Summer	Seawater	2001		Wild	0	2	
Inriver	1999	Snake R	Summer	Seawater	2002	Female	Hatchery	0	3	87
Inriver	1999	Clearwater R	Summer	Seawater	2000	Male	Hatchery	0	1	51
Inriver	1999	Clearwater R	Summer	Seawater	2002	Male	Hatchery	0	3	87
Inriver	1999	Snake R	Summer	Seawater	2000	Male	Hatchery	0	1	49
Inriver	1999	Clearwater R	ND	Unknown	2000	Male	Hatchery	1	0	40
Inriver	1999	Snake R	Summer	Seawater	2001		Wild	0	2	
Inriver	1999	Snake R	Summer	Seawater	2001		Wild	0	2	
Inriver	2001	Snake R	Summer	Unknown	2005	Male	Wild	1	3	101
Inriver	2001	Snake R	ND	Unknown	2004		Hatchery	1	2	
Inriver	2001	Clearwater R	Summer	Unknown	2004		Hatchery	1	2	
Inriver	2001	Snake R	Summer	Unknown	2003	Male	Hatchery	1	1	52
Inriver	2001	Clearwater R	Spring	Reservoir	2003	Female	Hatchery	1	1	60
Inriver	2001	Snake R	Spring	Reservoir	2003	Male	Hatchery	1	1	50
Inriver	2001	Snake R	ND	Unknown	2006	Male	Wild	1	4	74
Inriver	2001	Snake R	ND	Unknown	2004		Hatchery	1	2	
Inriver	2001	Snake R	Spring	Reservoir	2003	Male	Hatchery	1	1	50
Inriver	2001	Snake R	ND	Unknown	2003	Male	Hatchery	1	1	48
Inriver	2002	Snake R	ND	Unknown	2004		Hatchery	1	1	
Inriver	2002	Snake R	Spring	Reservoir	2005	Female	Hatchery	1	2	70
Inriver	2002	Snake R	ND	Unknown	2003	Male	Hatchery	1	0	41
Inriver	2002	Snake R	Summer	Unknown	2004		Hatchery	1	1	
Inriver	2002	Snake R	Spring	Reservoir	2004		Hatchery	1	1	
Inriver	2002	Snake R	ND	Unknown	2004		Hatchery	1	1	
Inriver	2002	Snake R	ND	Seawater	2004		Hatchery	0	2	

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Life History/Survival Studies (Continued)										
Inriver	2002	Snake R	ND	Seawater	2005	Female	Wild	0	3	82
Inriver	2002	Snake R	ND	Unknown	2004		Hatchery	1	1	
Inriver	2003	Snake R	Summer	Seawater	2005	Male	Wild	0	2	71
Inriver	2003	Snake R	Spring	Reservoir	2005	Male	Wild	1	1	61
Inriver	2003	Snake R	Summer	Seawater	2005	Male	Wild	0	2	60
Inriver	2003	Snake R	Summer	Unknown	2005	Male	Wild	1	1	57
Inriver	2004	Snake R	Summer	Seawater	2005	Male	Wild	0	1	52
Inriver	2004	Snake R	Summer	Seawater	2006	Male	Wild	0	2	77
Inriver	2001	Snake R	ND	Unknown	2005	Female	Hatchery	1	3	83
Inriver	2001	Snake R	ND	Unknown	2005	Female	Hatchery	1	3	76
Inriver	2001	Snake R	ND	Unknown	2005	Female	Hatchery	1	3	77
Transport-S	2002	Snake R	Summer	Seawater	2006	Female	Hatchery	0	4	80
Transport Studies										
Inriver	2002	Snake R	ND	Seawater	2006	Male	Hatchery	0	4	86
Inriver	2002	Snake R	ND	Unknown	2005	Female	Hatchery	1	2	67
Transport-S	2002	Snake R	Summer	Freshwater/Estuary	2005	Female	Hatchery	1	2	81
Transport-S	2002	Snake R	Summer	Seawater	2005	Female	Hatchery	0	3	76
Inriver	2002	Snake R	Summer	Seawater	2005	Female	Hatchery	0	3	72
Transport-F	2002	Snake R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	3	73
Transport-F	2002	Snake R	Fall	Freshwater/Estuary	2006	Female	Hatchery	1	3	81
Inriver	2002	Snake R	ND	Unknown	2006	Female	Hatchery	1	3	87
Transport-S	2002	Snake R	Summer	Freshwater/Estuary	2005	Female	Hatchery	1	2	66
Transport-S	2002	Snake R	Summer	Seawater	2006	Female	Hatchery	0	4	88
Transport-S	2002	Snake R	Summer	Freshwater/Estuary	2005	Female	Hatchery	1	2	74
Transport-S	2002	Snake R	Summer	Seawater	2005	Male	Hatchery	0	3	72
Transport-S	2002	Snake R	Summer	Seawater	2006	Female	Hatchery	0	4	82
Inriver	2002	Snake R	ND	Unknown	2006	Female	Hatchery	1	3	62

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Transport Studies (Continued)										
Inriver	2002	Snake R	ND	Unknown	2005	Female	Hatchery	1	2	75
Inriver	2002	Snake R	Spring	Reservoir	2005	Male	Hatchery	1	2	69
Transport-F	2002	LGR	Fall	Seawater	2006	Male	Hatchery	0	4	87
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Male	Hatchery	1	2	76
Inriver	2002	Snake R	Spring	Reservoir	2005	Female	Hatchery	1	2	69
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Male	Hatchery	1	2	73
Transport-F	2002	LGR	Fall	Seawater	2005	Female	Hatchery	0	3	75
Transport-F	2002	Snake R	Fall	Freshwater/Estuary	2006	Female	Hatchery	1	3	76
Inriver	2002	Snake R	Spring	Reservoir	2005	Female	Hatchery	1	2	76
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Female	Hatchery	1	2	78
Transport-S	2002	Snake R	Summer	Seawater	2005	Male	Hatchery	0	3	75
Inriver	2002	Snake R	Spring	Reservoir	2005	Female	Hatchery	1	2	72
Transport-F	2002	Snake R	Fall	Freshwater/Estuary	2005	Male	Hatchery	1	2	74
Transport-S	2002	Snake R	Summer	Freshwater/Estuary	2006	Female	Hatchery	1	3	84
Transport-S	2002	Snake R	Summer	Seawater	2005	Female	Hatchery	0	3	80
Inriver	2002	Snake R	Spring	Reservoir	2005	Male	Hatchery	1	2	71
Transport-F	2002	Snake R	Fall	Seawater	2005	Female	Hatchery	0	3	73
Inriver	2002	Snake R	Spring	Reservoir	2006	Female	Hatchery	1	3	82
Inriver	2002	Snake R	Spring	Reservoir	2005	Female	Hatchery	1	2	82
Transport-S	2002	Snake R	Summer	Seawater	2005	Male	Hatchery	0	3	65
Inriver	2002	Snake R	Summer	Seawater	2005	Male	Hatchery	0	3	72
Transport-S	2002	Snake R	Summer	Seawater	2005	Male	Hatchery	0	3	74
Inriver	2002	Snake R	ND	Unknown	2005	Female	Hatchery	1	2	67
Inriver	2002	Snake R	ND	Unknown	2005	Male	Hatchery	1	2	61
Inriver	2002	Snake R	Spring	Reservoir	2005	Male	Hatchery	1	2	76
Inriver	2002	Snake R	ND	Unknown	2005	Male	Hatchery	1	2	49
Inriver	2002	Snake R	Spring	Reservoir	2005	Female	Hatchery	1	2	55

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Transport Studies (Continued)										
Inriver	2002	Snake R	Summer	Seawater	2005	Female	Hatchery	0	3	76
Transport-S	2002	Snake R	Summer	Freshwater/Estuary	2005	Male	Hatchery	1	2	67
Inriver	2002	Snake R	ND	Unknown	2005	Female	Hatchery	1	2	77
Transport-F	2002	Snake R	Fall	Freshwater/Estuary	2005	Female	Hatchery	1	2	74
Transport-F	2002	LGR	Fall	Seawater	2006	Female	Hatchery	0	4	80
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Male	Hatchery	1	2	80
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2006	Female	Hatchery	1	3	83
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2006	Female	Wild	1	3	83
Transport-F	2002	LGR	Fall	Seawater	2006	Female	Hatchery	0	4	90
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Female	Hatchery	1	2	77
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Female	Wild	1	2	79
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2006	Female	Hatchery	1	3	78
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2006	Female	Hatchery	1	3	78
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2006	Female	Wild	1	3	85
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Male	Hatchery	1	2	67
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Female	Hatchery	1	2	77
Transport-F	2002	LGR	Fall	Freshwater/Estuary	2005	Male	Wild	1	2	79
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2006	Female	Hatchery	1	2	72
Transport-F	2003	LGR	Fall	Seawater	2006	Female	Wild	0	3	84
Transport-F	2003	LGR	Fall	Seawater	2006	Male	Wild	0	3	73
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2005	Female	Wild	1	1	69
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2006	Female	Hatchery	1	2	83
Transport-F	2003	LGR	Fall	Seawater	2006	Male	Wild	0	3	89
Transport-F	2003	LGR	Fall	Seawater	2005	Male	Wild	0	2	63
Transport-F	2003	LGR	Fall	Seawater	2005	Male	Hatchery	0	2	61
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2005	Female	Hatchery	1	1	69
Transport-F	2003	LGR	Fall	Seawater	2006	Female	Wild	0	3	93

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Transport Studies (Continued)										
Transport-F	2003	LGR	Fall	Seawater	2006	Male	Hatchery	0	3	87
Transport-F	2003	LGR	Fall	Seawater	2006	Male	Wild	0	3	84
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	2	89
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2005	Male	Hatchery	1	1	65
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2005	Female	Hatchery	1	1	70
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	2	69
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2005	Male	Wild	1	1	62
Transport-F	2003	LGR	Fall	Seawater	2006	Male	Hatchery	0	3	60
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	2	73
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2006	Female	Hatchery	1	2	84
Transport-S	2003	Snake R	Summer	Seawater	2005	Male	Hatchery	0	2	70
Transport-S	2003	Snake R	Summer	Seawater	2005	Male	Hatchery	0	2	73
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	2	93
Inriver	2003	Snake R	ND	Unknown	2006	Male	Hatchery	1	2	78
Transport-F	2003	LGR	Fall	Seawater	2006	Male	Wild	0	3	78
Inriver	2003	Snake R	Summer	Unknown	2005	Male	Hatchery	1	1	67
Transport-S	2003	Snake R	Summer	Seawater	2005	Male	Hatchery	0	2	62
Transport-S	2003	Snake R	Summer	Seawater	2005	Male	Hatchery	0	2	63
Inriver	2003	Snake R	ND	Unknown	2005	Male	Hatchery	1	1	56
Inriver	2003	Snake R	Summer	Seawater	2005	Male	Hatchery	0	2	75
Transport-S	2003	Snake R	Summer	Seawater	2005	Male	Hatchery	0	2	67
Transport-F	2003	LGR	Fall	Seawater	2005	Male	Hatchery	0	2	73
Transport-F	2003	LGR	Fall	Seawater	2005	Male	Wild	0	2	71
Transport-F	2003	LGR	Fall	Seawater	2005	Male	Wild	0	2	63
Transport-F	2003	LGR	Fall	Seawater	2005	Male	Hatchery	0	2	66
Transport-F	2003	LGR	Fall	Seawater	2006	Male	Wild	0	3	88
Transport-F	2003	LGR	Fall	Seawater	2005	Male	Wild	0	2	68

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Transport Studies (Continued)										
Transport-F	2003	LGR	Fall	Freshwater/Estuary	2005	Male	Wild	1	1	55
Transport-F	2003	LGR	Fall	Seawater	2006	.	U	0	3	71
Inriver	2003	Snake R	Spring	Reservoir	2006	Female	Hatchery	1	2	76
Transport-S	2003	Snake R	Summer	Freshwater/Estuary	2005	Male	Hatchery	1	1	68
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	1	66
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2005	Male	Wild	1	0	44
Transport-F	2004	LGR	Fall	Seawater	2006	Male	Wild	0	2	63
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	1	67
Transport-F	2004	LGR	Fall	Seawater	2005	Male	Hatchery	0	1	40
Transport-F	2004	LGR	Fall	Seawater	2005	Male	Hatchery	0	1	47
Transport-F	2004	LGR	Fall	Seawater	2005	Male	Wild	0	1	45
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2005	Male	Hatchery	1	0	47
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	1	65
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	1	67
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	1	48
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	1	64
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2005	Male	Wild	1	0	36
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2005	Male	Wild	1	0	49
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	1	60
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	1	59
Transport-F	2004	LGR	Fall	Seawater	2006	Male	Wild	0	2	62
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	1	66
Transport-S	2004	LGR	Summer	Seawater	2005	Male	Hatchery	0	1	42
Transport-F	2004	LGR	Fall	Freshwater/Estuary	2005	Male	Hatchery	1	0	44
Inriver	2004	LGR	Summer	Seawater	2006	Male	Hatchery	0	2	68
Transport-S	2004	LGR	Summer	Seawater	2006	Male	Hatchery	0	2	70
Transport-F	2004	LGR	Fall	Seawater	2005	Male	Wild	0	1	46

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Transport Studies (Continued)										
Transport-S	2004	LGR	Summer	Freshwater/Estuary	2005	Male	Hatchery	1	0	45
Transport-S	2004	LGR	Summer	Seawater	2006	Female	Hatchery	0	2	73
Transport-S	2004	LGR	Summer	Seawater	2005	Male	Hatchery	0	1	45
Transport-S	2004	LGR	Summer	Seawater	2006	Male	Hatchery	0	2	69
Transport-S	2004	LGR	Summer	Seawater	2005	Male	Hatchery	0	1	54
Transport-S	2004	LGR	Summer	Seawater	2006	Male	Hatchery	0	2	60
Transport-S	2004	LGR	Summer	Seawater	2006	Male	Hatchery	0	2	69
Transport-S	2004	LGR	Summer	Freshwater/Estuary	2005	Male	Hatchery	1	0	39
Inriver	2004	LGR	Spring	Reservoir	2006	Male	Hatchery	1	1	55
Inriver	2004	LGR	Fall	Unknown	2005	Male	Hatchery	1	0	54
Inriver	2004	LGR	Fall	Seawater	2005	Male	Wild	0	1	52
Inriver	2004	LGR	Spring	Reservoir	2006	.	U	1	1	64
Inriver	2004	LGR	Summer	Seawater	2006	Male	Hatchery	0	2	62
Transport-F	2004	LGR	Fall	Seawater	2006	Male	Wild	0	2	62
Transport-S	2004	LGR	Summer	Seawater	2006	Male	Hatchery	0	2	64
Dam Passage Strategy Study										
Transport-F	2005	Clearwater R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	44
Inriver	2005	Snake	ND	Seawater	2006	Male	Hatchery	0	1	42
Inriver	2005	Snake	Summer	Seawater	2006	Male	Hatchery	0	1	47
Inriver	2005	Snake	ND	Unknown	2006	Male	Wild	1	0	45
Inriver	2005	Snake	ND	Seawater	2006	Male	Wild	0	1	45
Inriver	2005	Clearwater R	Spring	Reservoir	2006	Male	Hatchery	1	0	42
Transport-S	2005	Clearwater R	Summer	Seawater	2006	Male	Hatchery	0	1	52
Inriver	2005	Clearwater R	ND	Unknown	2006	Male	Hatchery	1	0	42
Inriver	2005	Snake	Summer	Seawater	2006	Male	Hatchery	0	1	52
Inriver	2005	Snake	Summer	Seawater	2006	Male	Hatchery	0	1	45

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Dam Passage Strategy Study (Continued)										
Inriver	2005	Snake	Summer	Seawater	2006	Male	Hatchery	0	1	46
Inriver	2005	Snake	ND	Seawater	2006	Male	Hatchery	0	1	46
Inriver	2005	Snake	Summer	Seawater	2006	Male	Hatchery	0	1	43
Inriver	2005	Snake	ND	Seawater	2006	Male	Hatchery	0	1	49
Transport-F	2005	Clearwater R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	44
Inriver	2005	Snake	ND	Unknown	2006	Male	Hatchery	1	0	41
Transport-F	2005	Clearwater R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	46
Inriver	2005	Snake	Summer	Seawater	2006	Male	Hatchery	0	1	48
Transport-F	2005	Clearwater R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	41
Inriver	2005	Clearwater R	Spring	Reservoir	2006	Male	Hatchery	1	0	44
Transport-F	2005	Clearwater R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	44
Inriver	2005	Clearwater R	ND	Seawater	2006	Male	Hatchery	0	1	45
Inriver	2005	Clearwater R	Spring	Reservoir	2006	Male	Hatchery	1	0	41
Inriver	2005	Clearwater R	ND	Unknown	2006	Male	Hatchery	1	0	43
Transport-F	2005	Clearwater R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	47
Inriver	2005	Clearwater R	Fall	Unknown	2006	Male	Hatchery	1	0	44
Inriver	2005	Clearwater R	ND	Unknown	2006	Male	Hatchery	1	0	39
Inriver	2005	Clearwater R	Spring	Reservoir	2006	Male	Hatchery	1	0	47
Inriver	2005	Snake	ND	Seawater	2006	Male	Hatchery	0	1	46
Inriver	2005	Clearwater R	Spring	Reservoir	2006	Male	Hatchery	1	0	38
Inriver	2005	Snake	ND	Seawater	2006	Male	Hatchery	0	1	51
Transport-S	2005	Clearwater R	Summer	Seawater	2006	Male	Hatchery	0	1	51
Inriver	2005	Clearwater R	Fall	Unknown	2006	Male	Hatchery	1	0	46
Transport-F	2005	Clearwater R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	46
Inriver	2005	Clearwater R	ND	Unknown	2006	Male	Hatchery	1	0	42
Transport-F	2005	Clearwater R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	50
Inriver	2005	Clearwater R	ND	Unknown	2006	Male	Hatchery	1	0	43

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Dam Passage Strategy Study (Continued)										
Inriver	2005	Clearwater R	ND	Seawater	2006	Male	Hatchery	0	1	44
Inriver	2005	Clearwater R	Fall	Unknown	2006	Male	Hatchery	1	0	43
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	0	41
Inriver	2005	Snake R	ND	Unknown	2006	Male	Hatchery	1	0	41
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	46
Inriver	2005	Snake R	ND	Seawater	2006	Male	Wild	0	1	49
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Wild	0	1	49
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Wild	0	1	43
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	45
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	40
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	51
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	0	43
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	44
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	0	43
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	0	46
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	0	47
Transport-F	2005	LGR	Fall	Seawater	2006	Male	Hatchery	0	1	55
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	0	47
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Wild	1	0	49
Inriver	2005	Clearwater R	ND	Unknown	2006	Male	Hatchery	1	0	40
Transport-F	2005	LGR	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	32
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Hatchery	0	1	46
Inriver	2005	Snake R	ND	Unknown	2006	Male	Hatchery	1	0	38
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Hatchery	0	1	41
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Hatchery	0	1	47
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	51
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	43

Appendix Table 1. Continued.

Migration pathway	Migration year	Release site	Last detection	First-year wintering location	Return year	Gender	Origin	Age at Ocean Entry	Ocean age	Fork length (cm)
Dam Passage Strategy Study (Continued)										
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	49
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	46
Transport-S	2005	Snake R	Summer	Seawater	2006	Male	Hatchery	0	1	46
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Hatchery	0	1	59
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Hatchery	0	1	52
Inriver	2005	Snake R	ND	Unknown	2006	Male	Hatchery	1	0	42
Transport-F	2005	Snake R	Fall	Freshwater/Estuary	2006	Male	Hatchery	1	0	48
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	46
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	48
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	42
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	42
Inriver	2005	Snake R	ND	Seawater	2006	Male	Hatchery	0	1	49
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Hatchery	0	1	46
Inriver	2005	Snake R	Summer	Seawater	2006	Male	Hatchery	0	1	44

Appendix Table 2. Estimated survival and detection probabilities for downstream migrating wild and hatchery subyearling fall Chinook salmon during 1995-2001. Estimates are from the studies of Connor et al. (2003b) and Smith et al. (2003). The probability of a PIT-tagged juvenile surviving and actively migrating from release to the tailrace of Lower Monumental Dam without being detected at any of the three dams (ND) was estimated as:
$(S_{LGR}(1\text{-}P_{LGR}))(S_{LGO}\ (1\text{-}P_{LGO}))(S_{LMO}\ (1\text{-}\ P_{LMO}))$.

Date of	Lower Granite Dam		Little Goose Dam		Lower Monumental Dam		
release	Survival	Detection	Survival	Detection	Survival	Detection	ND
				Wild Origin			
05/20/1998	0.708	0.483	0.943	0.636	0.874	0.409	0.065
05/21/1998	0.661	0.434	0.805	0.707	0.853	0.549	0.034
06/02/1998	0.528	0.482	0.845	0.603	0.818	0.449	0.041
06/16/1998	0.356	0.534	0.762	0.586	0.782	0.400	0.025
05/27/1999	0.877	0.390	0.767	0.693	1.000	0.500	0.063
06/02/1999	0.770	0.455	0.841	0.608	1.000	0.431	0.079
06/01/1999	0.812	0.434	0.569	0.626	1.000	0.398	0.059
06/16/1999	0.364	0.624	0.486	0.757	0.755	0.497	0.006
05/09/2000	0.571	0.474	0.891	0.534	0.849	0.366	0.067
05/23/2000	0.534	0.576	0.688	0.686	0.718	0.457	0.019
05/25/2000	0.444	0.642	0.764	0.685	0.641	0.477	0.013
06/06/2000	0.357	0.632	0.494	0.657	0.906	0.366	0.013
				Hatchery Origin			
05/31/1995	0.656	0.477	0.846	0.396	0.792	0.478	0.072
06/07/1995	0.648	0.506	0.840	0.395	0.755	0.531	0.058
06/14/1995	0.596	0.463	0.705	0.432	0.864	0.445	0.061
06/01/1995	0.644	0.474	0.804	0.431	0.871	0.488	0.069
06/08/1995	0.594	0.497	0.907	0.388	0.748	0.514	0.060
06/15/1995	0.594	0.452	0.777	0.431	0.792	0.484	0.059
06/19/1995	0.499	0.494	0.766	0.358	0.847	0.357	0.068
06/27/1995	0.460	0.470	0.650	0.376	0.863	0.286	0.061
07/05/1995	0.388	0.416	0.562	0.256	0.850	0.168	0.067
06/06/1996	0.559	0.612	0.907	0.322	0.727	0.404	0.058
06/13/1996	0.528	0.628	0.925	0.290	0.780	0.345	0.066
06/20/1996	0.391	0.576	0.776	0.267	0.730	0.447	0.038
06/27/1996	0.247	0.569	0.736	0.256	0.668	0.286	0.028
07/03/1996	0.124	0.550	0.425	0.353	0.727	0.333	0.007
07/10/1996	0.054	0.591	0.556	0.200	0.500	0.375	0.003
06/06/1996	0.567	0.579	0.829	0.382	0.819	0.424	0.058
06/13/1996	0.545	0.640	0.794	0.364	0.826	0.393	0.050

Appendix Table 2. Continued.

Date of release	Lower Granite Dam Survival	Lower Granite Dam Detection	Little Goose Dam Survival	Little Goose Dam Detection	Lower Monumental Dam Survival	Lower Monumental Dam Detection	ND
	Hatchery Origin (continued)						
06/20/1996	0.362	0.667	0.672	0.343	0.797	0.392	0.026
06/27/1996	0.262	0.537	0.665	0.302	0.633	0.297	0.025
07/03/1996	0.134	0.625	0.298	0.375	0.903	0.385	0.005
07/10/1996	0.063	0.729	0.664	0.255	0.286	0.250	0.002
06/13/1996	0.571	0.576	0.697	0.343	0.701	0.423	0.045
06/20/1996	0.538	0.503	0.476	0.335	0.725	0.348	0.040
06/03/1997	0.573	0.436	0.520	0.555	0.496	0.474	0.020
06/10/1997	0.622	0.429	0.362	0.677	0.785	0.403	0.019
06/17/1997	0.582	0.478	0.529	0.495	0.590	0.473	0.025
06/24/1997	0.488	0.473	0.536	0.577	0.828	0.397	0.029
07/01/1997	0.237	0.515	0.515	0.481	0.489	0.400	0.009
06/03/1997	0.755	0.331	0.302	0.509	0.517	0.433	0.022
06/10/1997	0.595	0.458	0.332	0.563	0.572	0.523	0.013
06/17/1997	0.562	0.489	0.535	0.584	0.579	0.587	0.015
06/24/1997	0.497	0.507	0.583	0.474	0.582	0.505	0.022
07/01/1997	0.310	0.456	0.500	0.507	0.453	0.385	0.012
07/08/1997	0.093	0.606	0.949	0.243	0.077	1.000	0.000
06/03/1997	0.547	0.421	0.343	0.589	0.538	0.515	0.012
06/10/1997	0.390	0.470	0.262	0.586	0.483	0.509	0.005
06/17/1997	0.401	0.457	0.405	0.525	0.595	0.600	0.010
06/24/1997	0.285	0.427	0.345	0.621	0.512	0.633	0.004
07/01/1997	0.195	0.440	0.330	0.375	0.412	0.533	0.004
05/28/1997	0.676	0.390	0.832	0.499	0.738	0.493	0.064
05/30/1997	0.652	0.413	0.827	0.507	0.718	0.494	0.057
06/02/1998	0.502	0.465	0.763	0.658	0.904	0.479	0.033
06/09/1998	0.512	0.521	0.768	0.618	0.963	0.394	0.042
06/16/1998	0.480	0.509	0.740	0.597	0.875	0.392	0.037
06/23/1998	0.236	0.407	0.655	0.570	0.822	0.404	0.019
06/30/1998	0.165	0.466	0.566	0.558	0.909	0.395	0.012
06/02/1998	0.545	0.538	0.768	0.628	0.942	0.443	0.038
06/09/1998	0.517	0.485	0.719	0.660	1.042	0.376	0.042
06/16/1998	0.486	0.477	0.754	0.600	0.806	0.470	0.033
06/23/1998	0.284	0.473	0.714	0.610	0.880	0.407	0.022
06/30/1998	0.249	0.447	0.656	0.502	0.980	0.311	0.030
07/07/1998	0.237	0.440	0.544	0.533	0.794	0.438	0.015
06/02/1998	0.516	0.468	0.709	0.621	0.949	0.428	0.040
06/09/1998	0.595	0.510	0.799	0.585	0.798	0.439	0.043
06/16/1998	0.487	0.496	0.709	0.616	0.966	0.417	0.038
06/23/1998	0.407	0.512	0.697	0.595	0.836	0.424	0.027
06/30/1998	0.382	0.419	0.498	0.571	0.862	0.421	0.024
07/07/1998	0.248	0.410	0.460	0.603	0.800	0.422	0.012
06/04/1998	0.763	0.471	0.822	0.611	0.930	0.392	0.073
06/05/1998	0.658	0.467	0.778	0.601	0.926	0.411	0.059

Appendix Table 2. Continued.

Date of release	Lower Granite Dam		Little Goose Dam		Lower Monumental Dam		
	Survival	Detection	Survival	Detection	Survival	Detection	ND
	Hatchery Origin (continued)						
06/01/1999	0.478	0.370	0.713	0.506	0.695	0.477	0.039
06/08/1999	0.449	0.480	0.630	0.575	1.012	0.309	0.044
06/15/1999	0.250	0.589	0.570	0.526	1.145	0.188	0.026
06/22/1999	0.269	0.610	0.513	0.572	0.832	0.471	0.010
06/29/1999	0.080	0.640	0.428	0.500	0.550	0.545	0.002
06/01/1999	0.394	0.411	0.538	0.682	0.770	0.483	0.016
06/08/1999	0.347	0.439	0.645	0.628	1.179	0.300	0.039
06/15/1999	0.283	0.531	0.470	0.655	0.875	0.413	0.011
06/22/1999	0.220	0.638	0.437	0.524	0.967	0.255	0.012
06/29/1999	0.140	0.620	0.465	0.407	0.593	0.286	0.006
06/01/1999	0.375	0.391	0.621	0.564	0.917	0.362	0.036
06/08/1999	0.285	0.416	0.553	0.576	1.052	0.359	0.026
06/15/1999	0.250	0.526	0.503	0.644	1.002	0.347	0.014
06/22/1999	0.198	0.597	0.477	0.509	0.697	0.415	0.008
06/01/2000	0.152	0.648	0.798	0.632	0.852	0.421	0.008
06/08/2000	0.043	0.536	0.599	0.578	0.584	0.467	0.002
06/15/2000	0.087	0.550	0.648	0.648	0.576	0.514	0.002
06/29/2000	0.037	0.354	0.379	0.500	1.875	0.167	0.007
07/06/2000	0.015	0.579	0.750	0.500	0.667	1.000	0.000
06/01/2000	0.356	0.659	0.775	0.641	0.715	0.452	0.013
06/08/2000	0.193	0.722	0.812	0.568	0.828	0.310	0.011
06/15/2000	0.160	0.645	0.708	0.550	0.755	0.319	0.009
06/22/2000	0.101	0.636	0.713	0.554	0.642	0.479	0.004
06/29/2000	0.053	0.636	0.540	0.822	0.627	0.857	0.000
05/23/2001	0.113	0.647	0.716	0.695	0.865	0.278	0.005
05/30/2001	0.049	0.620	1.112	0.333	0.167	0.636	0.001
06/06/2001	0.020	0.433	0.897	0.524	0.300	0.500	0.001
05/23/2001	0.410	0.675	0.829	0.559	0.592	0.338	0.019
05/30/2001	0.289	0.673	0.828	0.559	0.598	0.342	0.014
06/06/2001	0.121	0.593	0.736	0.427	0.401	0.366	0.005